The M17 project

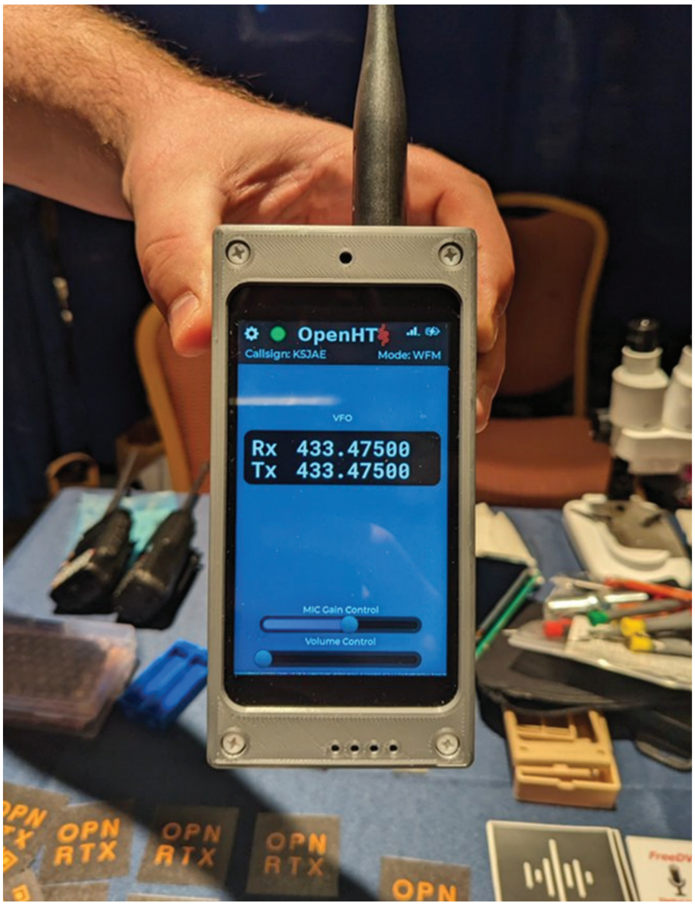


FIGURE 1: OpenHT, an open-source SDR-based handheld transceiver.

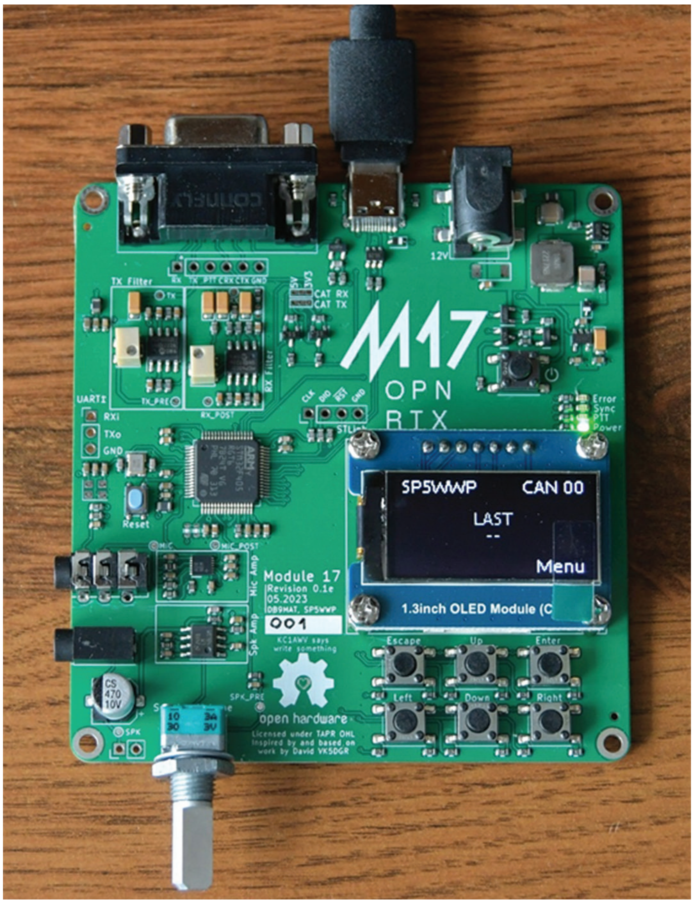


FIGURE 2: The Module 17 modem.

This is an open-source digital voice standard which promotes innovation, and which should attract young 'hardware hackers' to amateur radio.

Introduction

The freedom to design, build, and experiment has always been an important part of amateur radio. As our hobby migrates to digital voice technology, that freedom may be limited by proprietary technology used to code and decode the signals. What experimenters need is an open-source digital standard, ie a standard that anyone can use without having to buy a licence or pay royalties, and that anyone can extend or modify provided that they share their code with the amateur-radio community.

Digital voice (DV) in the UK's VHF and UHF bands is currently served by no fewer than seven different standards: System Fusion from Yaesu (YSF), digital mobile radio (DMR) from the European Telecommunications Standards Institute (ETSI), D-STAR from Icom, next-generation digital narrowband (NXDN) from Icom and Kenwood, project 25 (APCO P25) developed by public safety professionals in North America, terrestrial trunked radio (TETRA) developed by public safety and two-way radio industry experts together with ETSI, and M17 developed by a community of open-source developers and radio enthusiasts. Four of these standards use the proprietary advanced multi-band excitation (AMBE+2) codec (a codec is a device that converts analogue voice signals to digital signals for transmission, and digital signals to analogue voice signals on reception), designed and licensed by Digital Voice Systems Inc (DVSI). D-STAR and TETRA use older codecs: D-STAR uses AMBE and TETRA uses algebraic code-excited linear prediction (ACELP) that, while beyond its 20-year patent protection period, still contains proprietary elements. M17 uses the completely-free and open-source codec 2, developed specifically for amateur radio. A comparison between the various standards is shown in **Table 1**.

It's important to keep all roads to innovation open. Amateur radio operators have made significant contributions to the technology over the years. For instance, Louis Varney, G5RV invented his popular multiband antenna, and Edwin H. Armstrong, W2MXN invented FM radio.

Amateur radio enthusiasts, who hope to make contributions to digital voice technology, may encounter obstacles. When equipment manufacturers decided to offer digital voice, they had two options. They could develop codecs for amateur radio from scratch, not a trivial task, or they could license codecs already developed for commercial and public-safety markets. For reasons that made good business sense at the time, they decided to license existing technology. However, this created a couple of problems for home-brewers and experimenters. It meant that anyone making their own interoperable device would have to purchase a codec from a licensed manufacturer. That may not sound like a big imposition, but it limits the home-brewer's design choices. And anyone wanting to customise a commercially-manufactured radio might be prevented from doing so if the codec is implemented in firmware. The manufacturer might not care if it's just one radio, but what if that person decides to share their code by publishing it online?

There is another argument for developing codecs specifically for amateur radio. Although the licensed codecs are the result of years of development and experience in commercial and public-safety markets, they aren't optimised for amateur radio applications, which are exceptionally diverse and continue to evolve. Free and open-source codecs would give the amateur radio community greater control over its future.

M17 is a reasonable solution, both in terms of ensuring experimenters are free to experiment, and providing a way forward. The M17 specification, source code, hardware designs, and algorithms are all open. The software is licensed under the GNU general public licence version 2.0, and the hardware under the Tucson amateur packet radio (TAPR) open hardware licence. There is also a management system to facilitate sharing of source-code additions and changes.

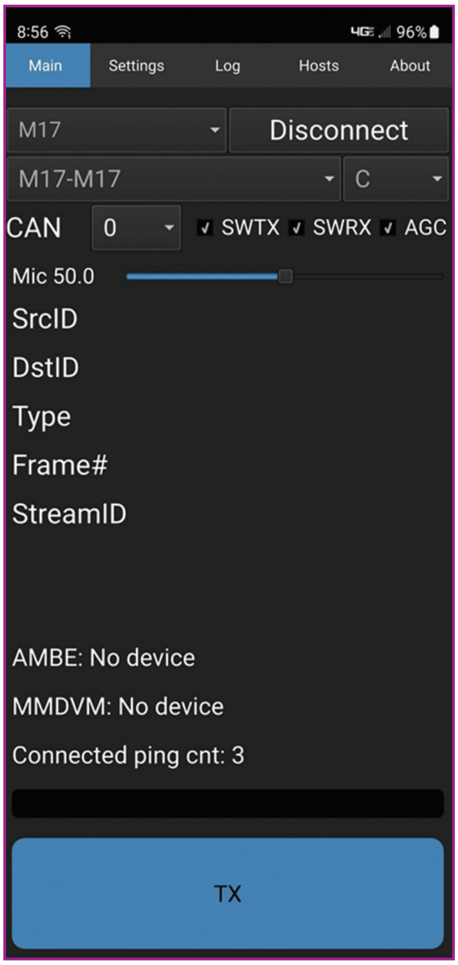
There is one more problem that M17 might be able solve. Because there are several different standards, radios can only talk to repeaters and other radios supporting the same standard. The market for VHF/UHF amateur radios is, therefore, quite fragmented. An open-source standard could serve as a vendor-neutral bridge between the standards, by enabling dual-mode mobile radios, handheld transceivers, hotspots, and repeaters (M17-YSF, M17-DMR, etc). This would promote greater interoperability, and would facilitate the long-term development of a universal digital voice standard for amateur radio, all while continuing to protect the manufacturers' investments in current standards.

Enter the M17 project

The M17 project was founded by Polish radio amateur Wojciech Kaczmarski, SP5WWP in 2019. The name 'M17' comes from the street address of a radio club in Warsaw (Mokotowska 17). After obtaining his licence in 2016, Kaczmarski began experimenting with Codec 2, the open-source codec developed by David Rowe, VK5DGR for FreeDV, some software for using digital voice in the HF bands. Kaczmarski wanted to create an alternative to the popular DMR standard, because the DMR specification is difficult to understand, and its proprietary codec inhibits 'hacking', a term many people use for building and modifying hardware. The effort attracted support, the project grew, and in 2021 Kaczmarski received the ARRL Technical Innovation Award for developing the M17 protocol.

The goal of the M17 project is to ensure that the amateur radio community has the freedom to build, learn, and innovate by creating and evolving a digital voice/data protocol specifically for amateur radio. M17 supporters believe that it will lead to more interesting products and that, in turn, will make amateur radio more attractive to young people.

Enthusiasm for designing, tinkering, and inventing is very much alive in the amateur-radio community. Recent examples include: multi-mode digital voice modem for hotspots and repeaters (MMDVM), high-performance software-defined radio (HPSDR), experimental firmware for select radios (OpenRTX), and multi-platform software for digital modes like PSK31 (Fldigi) and FT8 (WSJT-X). The M17 Project is driving the development of OpenHT, an open-source SDR-based handheld transceiver that operates in the 440MHz and 2.4GHz bands, and that supports a variety of modulation schemes (including AM, FM, SSB, 4FSK, and SSTV). OpenHT will enable amateur radio enthusiasts to build and customise small handheld transceivers (see **Figure 1**).



M17

M17-M17 C

CAN 0

Mic 50.0

AMBE: No device

MMDVM: No device

Connected ping cnt: 3

FIGURE 3: **Droidstar digital voice client software.**

Though proprietary technology has its place (for example the Apple computer), independent developers and experimenters tend to prefer open systems. Open systems drew many people to TCP/IP and Linux. TCP/IP triumphed because it was just good enough, easy to implement, and not proprietary. Linux provided an alternative to operating systems controlled by large corporations such as Microsoft and Apple.

M17 is already attracting young people; most M17 hackers are in their 20s or 30s. The M17 specification is relatively easy to understand, and can even be used as a digital communication teaching tool. M17 has also attracted financial grants: Amateur Radio Digital Communications (ARDC), a private foundation supporting amateur radio technology development, awarded the M17 Project $250,000 in 2021 and an additional $228,900 in 2022.

The M17 specification

The M17 specification can be viewed and downloaded at **[1]**. The specification defines three network layers: the physical layer, the data-link layer, and the application layer. The M17 protocol is versatile, supporting voice, point-to-point data, and telemetry. The M17 specification is also extensible so new capabilities may be added over time.

The physical layer describes the air interface: how ones and zeroes are represented over the air using 4-level frequency-shift keying (4FSK), the number of bits per symbol (2), and the symbol rate (4,800 symbols per second times 2 bits per symbol = 9,600 bits per second). M17 uses channels of width 9kHz with 12.5kHz spacing. Each transmission includes a preamble (to prepare the receiver), a synchronisation burst (to align the clock), the data payload, and an end-of-transmission marker.

The data-link layer describes how the data is organised into the four types of frames (link setup, bit error rate test, stream mode, and packet mode), and the error correction method. The link setup frames include the source and destination addresses. The bit error rate test frames are used to test hardware, and ensure interoperability between disparate devices. The stream frames are used to send continuous data such as voice. The packet frames are used to send data in packets of up to 823 bytes each. The throughput ranges from 3kbps to 4.7kbps, depending upon the packet size.

The application layer describes how various tasks are accomplished. For instance, it defines parameters for audio streaming using Codec 2, and the protocol (such as automatic packet reporting system (APRS), AX.25, etc) when transmitting packet data. Codec 2 offers good audio quality at low bit rates (1,600 or 3,200 bps). The application layer also defines parameters specific to user devices (clients), repeaters, and gateways (such as internet reflectors). M17 is designed to support IP networking for repeater linking and communicating via internet reflectors. M17 also supports strong encryption for use where legal (eg in Poland).

M17 development projects

There are currently several efforts underway to develop M17-capable hardware, as well as to adapt M17 to existing hardware. Repositories of software code for many of the following projects can be found at Github (see **[2]**). M17 community participants can also be found chatting on Discord **[3]**.

Module 17 **[4]** is a modem that sits between the microphone and radios capable of running 9600bps, such as the Kenwood V71 and D710, and the Motorola CDM series. Module 17's baseband output feeds into the radio's packet data input. See **Figure 2**.

The popular Digirig computer interface **[5]** can now be used to run M17 from a PC, using software and a soundcard, with radios such as the

Ira Brodsky, KC9TC
ibrodsky64@gmail.com

Yaesu FTM-200, FTM-300, FTM-400, and FTM-500. The Digirig cable is connected to the packet-data input and packet-data output pins.

Mobilinkd's TNC4 **[6]** is a hardware-based solution for adding M17 to a radio. It is an open-source TNC platform, and is also available in a bread-board configuration (NucleoTNC). The TNC4 and NucleoTNC provide alternatives to the PC-plus-soundcard approach.

The OpenRTX project **[7]** develops free and open-source firmware for digital amateur radio. The goal is to enable amateur radio operators and experimenters to customise and add features (such as voice prompts, different languages, and M17 support) to existing radios. Note that this project is being pursued independently of the manufacturers; changing the radio's firmware is carried out at the owner's risk, although users are encouraged to keep a backup copy of the factory firmware, which in most cases is easy to reinstall. OpenRTX could enable upgrading a DMR radio to a dual-mode DMR/M17 radio (assuming that there are no legal obstacles). Radios used in the OpenRTX project currently include Tytera MD-380/390, MD-UV380/390, and TYT MD-9600, Radioddity GD-77, and Baofeng DM-1801.

Multi-mode digital voice modem (MMDVM) **[8]** is an open-source hardware/software modem, developed by Jonathan Naylor, G4KLX that supports all amateur-radio digital voice standards, including M17. It is widely used in hotspots and repeaters. It runs on platforms that use ARM Cortex-M3, M4, or M7 processors, such as the Arduino Due. MMDVM_HS is José Andrés Uribe's (Andy, CA6JAU) hotspot version. MMDVM_CM is Doug McLain's, AD8DP solution for adding cross-mode capability to internet reflectors (eg M17 to YSF). M17Client, also by Jonathan Naylor, adds M17 to MMDVM modems and hotspots, and includes features such as voice, simultaneous text messaging, and GPS locating data.

WPSD **[9]** is a digital voice management suite of software for hotspots and repeaters that supports M17, DMR, D-Star, YSF, P25, and NXDN, and runs on the Raspberry Pi. The name is an acronym for 'W0CHP-PiStar-Dash', and is derived from the author's popular Pi-Star software. WPSD works with MMDVM, but doesn't do any encoding or decoding; it just takes data from the radio-modem combination and sends them over the network, and takes data from the network and sends them back to the radio via the modem.

Mvoice software **[10]** runs on Linux and can be used to transmit and receive M17 over the internet. A user with just a headset and a Raspberry Pi (or other Linux device) can use it to connect to an M17 reflector, and chat with other M17 users.

Mrefd **[11]** is an M17 reflector program that supports up to 26 channels. M17 clients (such as devices running Mvoice), M17 hotspots, M17 repeaters, and other M17 reflectors can be linked to each channel. The voice stream from each client is heard by all other clients on that channel. Mrefd runs on Linux (Debian or Ubuntu distribution recommended).

DroidStar **[12]** is digital voice client software that runs on multiple platforms (including Android, iOS, Linux, Windows, and MacOS) and supports multiple digital voice protocols (see **Figure 3**). It comes with M17 built-in; additional protocols require a plug-in voice encoder (vocoder). Droidstar can be used to talk directly over the internet or a radio and a modem can be added to turn a mobile phone into a hand-held transceiver.

M17 is also being integrated with software defined radio platforms. SDR++ software for Windows, MacOS, and Linux **[13]** includes a built-in M17 decoder. OpenWebRx, a web-based multi-user receiver **[14]** that can be operated from any web browser, will also support M17.

M17 and the future of amateur radio

In an increasingly digital and internet-connected world, it's essential that radio amateurs continue to develop their digital voice/data capabilities. An open-source standard is needed so that the entire amateur radio community, licensed operators as well as equipment manufacturers, can contribute to the process. M17 appears to be well-positioned to help make that happen.

References

[1] https://spec.m17project.org
[2] https://github.com/M17-Project
[3] https://discord.gg/G8zGphypf6
[4] https://github.com/M17-Project/Module_17
[5] https://digirig.net/
[6] https://store.mobilinkd.com/products/mobilinkd-tnc4
[7] https://openrtx.org/#/
[8] https://github.com/g4klx/MMDVM
[9] https://w0chp.radio/wpsd/
[10] https://github.com/n7tae/mvoice
[11] https://github.com/n7tae/mrefd
[12] https://github.com/nostar/DroidStar
[13] https://github.com/AlexandreRouma/SDRPlusPlus
[14] https://www.openwebrx.de/

Table 1: M17 compared with the other VHF/UHF digital voice standards used by radio amateurs in the UK.

	M17	System Fusion	DMR	D-STAR	NXDN	APCO P25	TETRA
Approx. number of Repeaters, UK	9	373	318	209	57	53	7
Developer/Vendors	Amateur radio community/ multivendor	Yaesu/Yaesu	European Telecomms Standards Institute/ multivendor	Japan Amateur Radio League/ Icom, Kenwood, and Flex	Icom and Kenwood/ multivendor	Association of Public Safety Comms Officials/ multivendor	European Telecomms Standards Institute/ multivendor
Type of standard	Free and open source	Proprietary	Partially open	Partially open	Partially open	Partially open	Partially open
Codec	Codec 2 (open source)	AMBE+2 (patent-protected)	AMBE+2 (patent-protected)	AMBE (copyright-protected)	AMBE+2 (patent-protected)	AMBE+2 (patent-protected)	ACELP (codebook-protected)
Modulation	4FSK	4FSK	4FSK	GMSK	4FSK	4FSK	DQPSK
Data features	Callsign, text messages, location, images	Callsign, text messages, location, images	Callsign, text messages, location	Callsign, text messages, location, images	Callsign, text messages, location	Callsign, text messages, location	Callsign, text messages, location
Advantages	Fully open source, created for amateur radio	Largest installed base of repeaters, WIRES-X	Well supported, talkgroups	Created for amateur radio, up to 128 kbps data	Can use 12.5 or 6.25 kHz channels	Designed for emergency communication	Supports four simultaneous conversations in 25 kHz
Disadvantages	Limited installed base (new entrant)	Single vendor	Designed for commercial use, difficult to set codeplug	Inferior codec, expensive	Designed for commercial & public safety, limited installed base	Mainly used gear for amateur use, not all models suitable for amateur radio	Equipment for amateur use limited to 430 MHz band